DESCRIPTION

REFRIGERATION SYSTEM

TECHNICAL FIELD

[0001] The present invention relates to a refrigeration system, particularly to a technique for improvement in actuation of a compressor under low outside air temperature condition.

BACKGROUND ART

[0002] So far, stores such as convenience stores use a refrigeration system in which a cold storage unit for displaying and keeping articles at low temperature in a cold storage showcase and a freezer unit for displaying and freezing articles in a freezer showcase are connected as a single refrigerant circuit.

[0003] FIG. **15** shows a refrigerant circuit diagram for briefly explaining the operation of a conventional refrigeration system (**5**).

[0004] In the refrigeration system (**5**), a refrigerant compressed in a compressor (**541**) in an outdoor unit (**54**) placed outdoor is condensed in a condenser (**542**) while it dissipates heat. The condensed liquid refrigerant is divided so that part thereof flows into a cold storage unit (**51**) and the other flows into a freezer unit (**52**). The refrigerant entered the cold storage unit (**51**) is depressurized by an expansion valve (**512**) and evaporated in a cold storage evaporator (**513**) while it absorbs heat of inside air. The refrigerant entered the freezer unit (**52**) is depressurized by an expansion valve (**522**) and evaporated in a freezer evaporator (**523**) while it absorbs heat of inside air.

[0005] Saturation pressure of the refrigerant in the freezer evaporator (**523**) is kept lower than that in the cold storage evaporator (**513**) by a booster compressor (**531**) in a booster unit (**53**). The evaporating temperature in the freezer evaporator (**523**) (about -5°C) is kept lower than that in the cold storage evaporator (**513**) (about 5°C).

[0006] As the cooling is continued, temperatures in the cold storage unit (**51**) and the

freezer unit (52) reach predetermined target temperatures, respectively. Then, an electromagnetic valve (511) and an electromagnetic valve (521) are closed and the refrigerant is no longer supplied to the evaporators (513) and (523) (the cold storage unit and the freezer unit enter a cold storage thermo-off state and a freezer thermo-off state, respectively).

[0007] In a control section (540) (including a microprocessor, a ROM, a RAM and the like for executing certain programs), a pressure sensor (546) is adapted to detect the pressure of the refrigerant sucked into the compressor (541). If the detected value is not higher than a predetermined value (e.g., 0.10 MPa), the control section (540) suspends the compressor (541) (an outdoor unit thermo-off state).

[0008] In the outdoor unit thermo-off state, when a certain temperature difference is observed between inside temperature and target inside temperature, the electromagnetic valve (511) of the cold storage unit (51) or the electromagnetic valve (521) of the freezer unit (52) is opened and a request for a refrigerant supply to the evaporator (513) or (523) is raised (a cold storage thermo-on state or a freezer thermo-on state). Further, the pressure sensor (546) of the control section (540) detects that the refrigerant suction pressure has increased to or above a predetermined value (e.g., 0.25 MPa). Accordingly, the control section (540) actuates the compressor (541) (an outdoor unit thermo-on state).

[0009] In the refrigeration unit (5) described above, the pressure sensor (546) makes it possible to determine whether or not it is necessary to circulate the refrigerant to either one of the evaporators (513, 523) to maintain the operation of the compressor (541). Therefore, there is no need of transmitting a signal indicating that the cooling is required in the cold storage unit (51) or the freezer unit (52) to the control section (540). Thus, the compressor (541) is easily switched between actuated state and suspended state with a simple structure.

[0010] For example, according to a similar refrigeration system of Japanese Patent Publication No. 2002-228297, the compressor is suspended when the refrigerant suction

pressure is not higher than a predetermined value to avoid operation in a wet state.

[0011] - Problem to solve -

According to the refrigeration system (5), in order to shift the outdoor unit from the thermo-off state to the thermo-on state, the compressor is controlled not to start working if the refrigerant suction pressure is lower than the predetermined value. However, if the outside air temperature is as low as -5°C or lower, for example, the saturation pressure of the refrigerant decreases to reduce the refrigerant pressure in the circuit. As a result, even if the freezer unit (52) requests cooling and the electromagnetic valve (513, 523) is opened, the refrigerant suction pressure may possibly remain low and the compressor (541) may not be actuated.

[0012] Under the circumstances, the present invention has been achieved. An object of the present invention is to provide a refrigeration system which makes it possible to actuate a compressor smoothly even if the outside air temperature is low.

DISCLOSURE OF THE INVENTION

[0013] The present invention solves the problem as described below.

[0014] A first aspect of the present invention is directed to a refrigeration system for vapor compression refrigeration cycle including a heat source circuit provided with a high temperature compressor (141) and a utilization circuit connected to the heat source circuit and provided with an evaporator (123) and a low temperature compressor (131). The refrigeration system includes an operation control means for switching the high temperature compressor (141) between actuated state and suspended state based on a refrigerant suction pressure; and an actuation control means for actuating the low temperature compressor (131) to increase the refrigerant suction pressure in the high temperature compressor (141) when the high temperature compressor (141) is suspended and given conditions including a condition concerning a request for cooling in the evaporator (123) are met.

[0015] According to the first aspect of the present invention, the high temperature compressor **(141)** is switched between actuated state and suspended state based on the refrigerant suction pressure. In the process of restarting the high temperature compressor **(141)** in the suspended state, if given conditions including a condition concerning a request for cooling in the evaporator **(123)** are met, the low temperature compressor **(131)** is actuated to increase the refrigerant suction pressure in the high temperature compressor **(141)**.

[0016] A second aspect of the present invention is directed to a refrigeration system for vapor compression refrigeration cycle. The refrigeration system includes an operation control means for switching a compressor **(241)** between actuated state and suspended state based on a refrigerant suction pressure; and a reference value changing means for reducing a reference value of the refrigerant suction pressure for judging whether to actuate the compressor **(241)** or not when the compressor **(241)** is suspended and outside air temperature is reduced from a predetermined temperature.

[0017] According to the second aspect of the present invention, the compressor **(241)** is switched between actuated state and suspended state based on the refrigerant suction pressure. In the process of restarting the temperature compressor **(241)** in the suspended state, if the outside air temperature is reduced from the predetermined temperature, a reference value of the refrigerant suction pressure for judging whether to actuate the compressor **(241)** or not is reduced.

[0018] According to a third aspect of the present invention related to the second aspect of the present invention, the reference value changing means is adapted to reduce the reference value in stages based on the amount of reduction in outside air temperature from the predetermined temperature.

[0019] According to the third aspect of the present invention, the reference value is reduced in stages based on the amount of reduction in outside air temperature.

[0020] A fourth aspect of the present invention is directed to a refrigeration system for

vapor compression refrigeration cycle. The refrigeration system includes an operation control means for switching a compressor (**341**) between actuated state and suspended state based on a refrigerant suction pressure; and a power supply control means for supplying open phase current to a motor of the compressor (**341**) to increase the refrigerant suction pressure increases when the compressor (**341**) is suspended, an outside air temperature is reduced from a predetermined temperature and a condition concerning a request for cooling in an evaporator (**313**) is met.

[0021] According to the fourth aspect of the present invention, the compressor (**341**) is switched between actuated state and suspended state based on the refrigerant suction pressure. In the process of restarting the compressor (**341**) in the suspended state, if the outside air temperature is reduced from the predetermined temperature and the condition concerning a request for cooling in the evaporator (**313**) is met, open phase current is supplied to the motor for driving the compressor (**341**) to increase the refrigerant suction pressure.

[0022] - Effect -

According to the first aspect of the present invention, in the process of restarting the high temperature compressor (**141**), if given conditions including a condition concerning a request for cooling in the evaporator (**123**) are met, the low temperature compressor (**131**) is actuated in advance of the actuation of the high temperature compressor (**141**) such that the refrigerant suction pressure of the high temperature compressor (**141**) increases. Therefore, even if the outside air temperature is significantly low, the refrigerant suction pressure of the high temperature compressor (**141**) surely increases. Thus, the high temperature compressor (**141**) is smoothly actuated.

[0023] According to the second aspect of the present invention, in the process of restarting the compressor (**241**), if the outside air temperature is lower than the predetermined temperature, the value of a refrigerant suction pressure which is a criterion for judging whether to actuate the compressor (**241**) or not is reduced. Therefore, the

compressor (**241**) is smoothly actuated even if the refrigerant pressure in the circuit is reduced due to the low outside air temperature.

[0024] According to the third aspect of the present invention, the reference value of the refrigerant suction pressure is reduced by a suitable amount based on the reduced amount of the outside air temperature, whereby the reduction in refrigerant suction pressure caused by the reduction in outside air temperature is detected with accuracy. Thus, the compressor is smoothly actuated in accordance with the detection result.

[0025] According to the fourth aspect of the present invention, in the process of restarting the compressor (**341**), if the condition concerning a request for cooling in the evaporator (**313**) is met, open phase current is supplied to the motor for driving the compressor (**341**). Therefore, even if the outside air temperature is reduced to a significant degree, the sucked refrigerant is heated to increase its pressure. Thus, the compressor (**341**) is smoothly actuated.

BRIEF DESCRIPTION OF DRAWINGS

[0026] FIG. **1** is a view illustrating the schematic structure of a refrigeration system according to a first embodiment of the present invention.

FIG. **2** is a view illustrating how the refrigeration system works in a normal state.

FIG. **3** is a view illustrating a characteristic feature of the present invention, i.e., how the refrigeration system enters a freezer thermo-on state under a low outside air temperature.

FIG. **4** is a block diagram schematically illustrating the major structure of a control program for entering an outdoor unit thermo-on state executed by a control section of an outdoor unit.

FIG. **5** is a flowchart illustrating the processing steps for entering a thermo-on state executed by the control section of the outdoor unit.

FIG. **6** is a flowchart illustrating the processing steps for controlling the

opening/closing of a cold storage electromagnetic valve executed by a control section of a cold storage unit.

FIG. **7** is a flowchart illustrating the processing steps for controlling the opening/closing of a freezer electromagnetic valve executed by a control section of a freezer unit.

FIG. **8** is a flowchart illustrating the processing steps for controlling the actuation/suspension of a booster compressor executed by the control section of the freezer unit.

FIG. **9** is a view illustrating how a refrigeration system of a second embodiment enters a cold storage thermo-on state under a low outside air temperature.

FIG. **10** is a block diagram schematically illustrating the major structure of a control program for entering an outdoor unit thermo-on state executed by a control section of an outdoor unit.

FIG. **11** is a flowchart illustrating the processing steps for entering a thermo-on state executed by the control section of the outdoor unit.

FIG. **12** is a view illustrating how a refrigeration system of a third embodiment enters a cold storage thermo-on state under a low outside air temperature.

FIG. **13** is a block diagram illustrating the major structure of a control program for entering an outdoor unit thermo-on state executed by a control section of an outdoor unit.

FIG. **14** is a flowchart illustrating the processing steps for entering a thermo-on state executed by the control section of the outdoor unit.

FIG. **15** is a refrigerant circuit diagram schematically illustrating how a conventional refrigeration system works.

BRIEF EXPLANATION OF REFERENCE NUMERALS

[0027] 1,2,3 Refrigeration system

113, 213, 313 Cold storage evaporator

123	Freezer evaporator
131	Booster compressor
141, 241, 341	Variable capacity compressor

BEST MODE FOR CARRYING OUT THE INVENTION

[0028] Hereinafter, a detailed explanation of refrigeration systems (**1**, **2**, **3**) as embodiments of the present invention will be provided with reference to the drawings.

[0029] FIG. **1** is a view schematically illustrating the structure of a refrigeration system (**1**) according to a first embodiment of the present invention.

[0030] The refrigeration system (**1**), which is placed in convenience stores and the like, includes a cold storage unit (**11**), a freezer unit (**12**), a booster unit (**13**) and an outdoor unit (**14**) as shown in FIG. **1**.

[0031] The cold storage unit (**11**) includes a cold storage showcase for displaying and keeping articles at low temperature and the freezer unit (**12**) includes a freezer showcase for displaying and freezing articles. The booster unit (**13**) keeps a refrigerant at low pressure for freezing. The outdoor unit (**14**) is disposed outdoor such that the refrigerant dissipates heat to outside air. The cold storage unit (**11**), freezer unit (**12**) and booster unit (**13**) are connected in parallel to the outdoor unit (**14**), thereby providing a single refrigerant circuit for two-step vapor compression refrigeration cycle.

[0032] In the cold storage unit (**11**), a temperature-sensitive expansion valve (**112**) for depressurizing the refrigerant is connected via a pipe with a cold storage evaporator (**113**) in which the refrigerant absorbs heat of inside air to evaporate. The cold storage unit (**11**) further includes a fan (**115**) for sending the inside air cooled in the cold storage evaporator (**113**) to the cold storage showcase. The cold storage unit (**11**) is further provided with a cold storage electromagnetic valve (**111**) which is opened or closed to pass through or block a refrigerant flow to the cold storage evaporator (**113**) and a temperature sensor (**114**) for detecting inside temperature.

[0033] The cold storage electromagnetic valve (**111**), temperature-sensitive expansion valve (**112**) and cold storage evaporator (**113**) are connected in series in this order along the path from an inlet pipe (**201**) to an outlet pipe (**202**).

[0034] Also in the freezer unit (**12**), a temperature-sensitive expansion valve (**122**) is connected via a pipe with a freezer evaporator (**123**) in which the refrigerant absorbs heat of inside air to evaporate. The freezer unit (**12**) further includes a fan (**125**) for sending the inside air cooled in the freezer evaporator (**123**) to the freezer showcase. The freezer unit (**12**) is further provided with a freezer electromagnetic valve (**121**) which is opened or closed to pass through or block a refrigerant flow to the freezer evaporator (**123**) and a temperature sensor (**124**) for detecting inside temperature.

[0035] The freezer electromagnetic valve (**121**), temperature-sensitive expansion valve (**122**) and freezer evaporator (**123**) are connected in series in this order along the path from an inlet pipe (**203**) to an outlet pipe (**204**).

[0036] The booster unit (**13**) includes a booster compressor (**131**). The booster compressor (**131**) keeps the pressure of the refrigerant passing through the freezer evaporator (**123**) lower than the pressure of the refrigerant passing through the cold storage evaporator (**113**).

[0037] The booster unit (**13**) further includes a bypass (**132**) having a check valve (**133**) for bypassing the booster compressor (**131**). When the booster compressor (**131**) fails to operate properly or stops, the bypass (**132**) allows the refrigerant to flow to the outdoor unit (**14**) without passing through the booster compressor (**131**). In other words, when the booster compressor (**14**) is working, the refrigerant does not pass through the bypass (**132**). The check valve (**133**) allows only the passage of the refrigerant flowing from an inlet pipe (**205**) to an outlet pipe (**206**).

[0038] The outdoor unit (**14**) includes a variable capacity compressor (**141**), a condenser (**142**) and a liquid receiver (**143**). The variable capacity compressor (**141**) is adapted to adjust its capacity depending on a cooling load of the cold storage unit (**11**), for

example. The condenser (**142**) is adapted to allow the refrigerant dissipate its heat to the outside air for condensation. The liquid receiver (**143**) temporarily stores a liquid refrigerant resulting from the condensation in the condenser (**142**). Specifically, in the refrigeration system (**1**), the variable capacity compressor (**141**) functions as a high temperature compressor and the booster compressor (**131**) functions as a low temperature compressor.

[0039] The outdoor unit (**14**) includes a fan (**144**) for taking the outside air into the condenser (**142**). The outdoor unit (**14**) further includes a temperature sensor (**145**) for detecting outside air temperature and a pressure sensor (**146**) for detecting the pressure of the refrigerant sucked into the variable capacity compressor (**141**).

[0040] The variable capacity compressor (**141**), condenser (**142**) and liquid receiver (**143**) are connected in series in this order along the path from an inlet pipe (**207**) to an outlet pipe (**208**).

[0041] The inlet pipe (**207**) of the outdoor unit (**14**) is connected to the outlet pipe (**206**) of the booster unit (**13**) and the outlet pipe (**202**) of the cold storage unit (**11**). The outlet pipe (**208**) of the outdoor unit (**14**) is connected to the inlet pipe (**201**) of the cold storage unit (**11**) and the inlet pipe (**203**) of the freezer unit (**12**). Further, the outlet pipe (**204**) of the freezer unit (**12**) is connected to the inlet pipe (**205**) of the booster unit (**13**).

[0042] The outdoor unit (**14**) is further provided with a control section (**140**). The control section (**140**) controls the capacity of the variable capacity compressor (**141**) such that the pressure of the refrigerant is kept uniform in each of the evaporators (**113, 123**). The control by the control section (**140**) according to the present invention will be explained with reference to FIGS. **4** to **8**.

[0043] The refrigeration system (**1**) works as shown in FIGS. **2** and **3**. FIG. **2** shows how the refrigeration system (**1**) works in a normal state and FIG. **3** shows a characteristic feature of the present invention, i.e., how the refrigeration system (**1**) enters a freezer thermo-on state under a low outside air temperature.

[0044] As shown in FIG. **2**, in the outdoor unit thermo-on state where the variable capacity compressor **(141)** is working, the electromagnetic valves **(111, 121)** are opened to shift the cold storage unit **(11)** to the cold storage thermo-on state and the freezer unit **(12)** to the freezer thermo-on state. More specifically, when the variable capacity compressor **(141)** is working, the compressed refrigerant is condensed in the condenser **(142)** while it dissipates heat. The condensed refrigerant passes through the liquid receiver **(143)** and divided such that part thereof flows into the cold storage unit **(11)** and the other flows into the freezer unit **(12)**.

[0045] In the cold storage unit **(11)**, the refrigerant depressurized by the expansion valve **(112)** is evaporated in the cold storage evaporator **(113)** while it absorbs heat, thereby cooling the air in the cold storage showcase. In the freezer unit **(12)**, the refrigerant depressurized by the expansion valve **(122)** is evaporated in the freezer evaporator **(123)** while it absorbs heat, thereby cooling the air in the freezer showcase. Then, the refrigerant coming out of the freezer unit **(12)** is compressed in the booster compressor **(131)**. The compressed refrigerant is sucked into the variable capacity compressor **(141)** of the outdoor unit **(14)** together with the refrigerant coming out of the cold storage unit **(11)**. In this way, the refrigerant circulation is repeated.

[0046] When the temperature in the cold storage showcase reaches a predetermined target temperature, the cold storage electromagnetic valve **(111)** is closed to block the refrigerant flow to the cold storage evaporator **(113)** (cold storage thermo-off state). In the same manner, if the temperature in the freezer showcase reaches a predetermined target temperature, the freezer electromagnetic valve **(121)** is closed and the booster compressor **(131)** is suspended to block the refrigerant flow to the freezer evaporator **(123)** (freezer thermo-off state). Under the cold storage thermo-off state and the freezer thermo-off state, the variable capacity compressor **(141)** decreases in refrigerant suction pressure. Once the reduction in refrigerant suction pressure is detected, the variable capacity compressor **(141)** is suspended to enter the outdoor unit thermo-off state.

[0047] In the normal state where the outside air temperature is higher than -5°C, a control section **(110)** of the control storage unit **(11)** automatically performs switching between the cold storage thermo-on/off states and a control unit **(120)** of the freezer unit **(12)** automatically performs switching between the freezer thermo-on/off states. Depending on the cold storage thermo-on/off states and the freezer thermo-on/off states, the control section **(140)** of the outdoor unit **(14)** automatically performs switching between the outdoor unit thermo-on/off states. The control sections **(110)** and **(120)** will be explained later with reference to FIG. **4**.

[0048] When the difference between the inside temperature of the freezer unit **(12)** and the target inside temperature is larger than a predetermined value, a request for a shift to the freezer thermo-on state is generated and the freezer electromagnetic valve **(121)** is opened. However, if the outside air temperature is as low as -5°C or lower, the variable capacity compressor **(141)** hardly increases the refrigerant suction pressure. According to a characteristic feature of the refrigeration system **(1)** of the present invention as shown in FIG. **3**, the booster compressor **(131)** is forcibly actuated before the variable capacity compressor **(141)** is driven such that the refrigerant suction pressure of the variable capacity compressor **(141)** increases.

[0049] Specifically, when a guard timer of the variable capacity compressor **(141)** expires, an R2 signal from the control section **(140)** of the outdoor unit **(14)** to the control section **(120)** of the freezer unit **(12)** is turned on (Action I). Then, if the control section **(120)** of the freezer unit **(12)** recognizes that a request for a shift to the freezer thermo-on state is raised according to the value of the inside temperature detected by the temperature sensor **(124)** (Action II), the freezer electromagnetic valve **(121)** is opened (Action III).

[0050] The guard timer of the variable capacity compressor **(41)** is used to prevent damage to the compressor by repetitive on-off switching in a short term and expires in 1 or 2 minutes after the suspension of the compressor.

[0051] When the freezer electromagnetic valve **(121)** is opened under the normal

condition, the refrigerant at the discharge side of the variable capacity compressor **(141)** is allowed to flow to the suction side of the variable capacity compressor **(141)** through the bypass **(132)** of the booster compressor **(131)**. As a result, the refrigerant suction pressure increases. When the increase in refrigerant suction pressure is detected by the pressure sensor **(146)**, the variable capacity compressor **(141)** is actuated. However, if the outside air temperature is significantly low, the refrigerant suction pressure of the variable capacity compressor **(141)** remains lower than the predetermined value. Therefore, the control section **(120)** of the freezer unit **(12)** forcibly actuates the booster compressor **(131)** (Action IV) to increase the refrigerant suction pressure of the variable capacity compressor **(141)**.

[0052] When the increase of the refrigerant suction pressure is detected by the pressure sensor **(146)** (Action V), the variable capacity compressor **(141)** is actuated in response to the detection result (Action VI).

[0053] The control processes by the refrigeration system **(1)** will be explained in detail with reference to FIGS. **4** to **8**.

[0054] FIG. **4** is a block diagram schematically illustrating the major structure of a control program for entering an outdoor unit thermo-on state executed by the control section **(140)** of the outdoor unit **(14)** and an input-output relationship between the control section **(140)**, the control section **(110)** of the cold storage unit **(11)** and the control unit **(120)** of the freezer unit **(12)**.

[0055] The control section **(140)** of the outdoor unit **(14)** executes a control program for entering the thermo-on state shown in FIG. **5**. The control section **(110)** of the cold storage unit **(11)** executes a control program for opening/closing the cold storage electromagnetic valve shown in FIG. **6**. The control unit **(120)** of the freezer unit **(12)** executes a control program for opening/closing the freezer electromagnetic valve and a control program for actuating/suspending the booster compressor. The control sections **(110, 120, 140)** execute the programs simultaneously.

[0056] The control section (**140**) of the outdoor unit (**14**) includes an electromagnetic valve open/close permission section (**1401**), a compressor actuating condition judging section (**1402**) and a compressor actuating section (**1403**).

[0057] The electromagnetic valve open/close permission section (**1401**) is adapted to turn on R1 and R2 signals for permitting the electromagnetic valves (**111, 121**) to open and the booster compressor (**131**) to start working after the guard timer of the variable capacity compressor (**141**) has expired. The compressor actuating condition judging section (**1402**) is adapted to judge whether or not refrigerant suction pressure LP detected by the pressure sensor (**146**) and outside air temperature Ta detected by the temperature sensor (**145**) are within the predetermined ranges, respectively. The compressor actuating section (**1403**) is adapted to actuate the variable capacity compressor (**141**) when the refrigerant suction pressure LP and the outside air temperature Ta are within the predetermined ranges, respectively.

[0058] The control section (**110**) of the cold storage unit (**11**) includes a cooling request judging section (**1102**) and an electromagnetic valve opening/closing section (**1102**).

[0059] The cooling request judging section (**1102**) judges whether or not the difference between the inside temperature detected by the temperature sensor (**114**) and a predetermined target temperature is not lower than a predetermined value (whether or not a request for a shift to the cold storage thermo-on state is raised). The cooling request judging section (**1102**) further judges whether the R1 signal is turned on or not. The electromagnetic valve opening/closing section (**1102**) is adapted to open the cold storage electromagnetic valve (**111**) when the request for a shift to the cold storage thermo-on state is raised and the R1 signal is turned on.

[0060] The control section (**120**) of the freezer unit (**12**) includes a cooling request judging section (**1201**), an electromagnetic valve opening/closing section (**1202**) and a booster compressor actuating/suspending section (**1203**).

[0061] The cooling request judging section (**1201**) judges whether or not the difference

between the inside temperature detected by the temperature sensor (124) and a predetermined target temperature is not lower than a predetermined value (whether or not a request for a shift to the freezer thermo-on state is raised). The cooling request judging section (1201) further judges whether the R2 signal is turned on or not. The electromagnetic valve opening/closing section (1202) is adapted to open the cold storage electromagnetic valve (121) when the request for a shift to the freezer thermo-on state is raised and the R2 signal is turned on. The booster compressor actuating/suspending section (1203) is adapted to actuate the booster compressor (131) when the request for a shift to the freezer thermo-on state is raised and the R2 signal is turned on.

[0062] In this case, the compressor actuating condition judging section (1402) and the compressor actuating section (1403) function as an operation control means for switching between actuation (thermo-on state) and suspension (thermo-off state) of the variable capacity compressor (141). Further, the cooling request judging section (1201), electromagnetic valve opening/closing section (1202) and booster compression actuating/suspending section (1203) function as an actuation control means for actuating the booster compressor (131) when given conditions are met, such as a request for cooling in the freezer unit (12) is raised and the guard timer of the variable capacity compressor (141) expires.

[0063] According to the programs executed by the control sections (110, 120, 140), even if the refrigerant suction pressure of the variable capacity compressor (141) is locally reduced due to a low outside air temperature, the booster compressor (131) is actuated to forcibly increase the refrigerant suction pressure of the variable capacity compressor (141). More specifically, the following processes are executed.

[0064] As shown in FIG. 5, in the control process for entering the thermo-on state executed by the control section (140) of the outdoor unit (14), judgment is made as to whether or not the guard timer of the variable capacity compressor (141) has expired (step 111, hereinafter indicated as ST111). If the guard timer has not expired (NO in ST111),

the process is ended. If the guard timer has expired (YES in ST111), the R1 signal for permitting the cold storage electromagnetic valve (**111**) to open is turned on and the R2 signal for permitting the freezer electromagnetic valve (**121**) to open and the booster compressor (**131**) to start working is turned on (ST112).

[0065] Subsequently, judgment is made as to whether or not the refrigerant suction pressure LP of the variable capacity compressor (**141**) is higher than 0.25 MPa (ST113). If the refrigerant suction pressure LP is higher than 0.25 MPa (YES in ST113), the variable capacity compressor (**141**) is actuated (ST114) and the process is ended.

[0066] If the refrigerant suction pressure LP is not higher than 0.25 MPa (NO in ST113), judgment is made as to whether or not the outside air temperature Ta detected by the temperature sensor (**145**) is lower than -5°C and whether or not the variable capacity compressor (**141**) has been suspended for 10 minutes or more (ST115). If these conditions are met (YES in ST115), the variable capacity compressor (**141**) is forcibly actuated in ST114. If the outside air temperature Ta is not lower than -5°C or the variable capacity compressor (**141**) has been suspended for less than 10 minutes (NO in ST115), the process is ended.

[0067] According to these processes, even if the refrigerant suction pressure is low and the variable capacity compressor (**141**) is not actuated, the R1 and R2 signals are turned on when the guard timer has expired. Thus, the control sections (**110**, **120**) permit the electromagnetic valves (**111**, **121**) to open and the booster compressor (**131**) to start working.

[0068] As shown in FIG. **6**, in the control process for opening/closing the cold storage electromagnetic valve executed by the control section (**110**) of the cold storage unit (**11**), judgment is made as to whether or not the difference between the inside temperature detected by the temperature sensor (**114**) and a predetermined target temperature is not lower than a predetermined value to raise a request for a shift to the cold storage thermo-on state (ST121). If the request for a shift to the cold storage thermo-on state is not raised

(NO in ST121), the cold storage electromagnetic valve (**111**) remains closed (ST122) and the process is ended.

[0069] If the request for a shift to the cold storage thermo-on state is raised (YES in ST121), judgment is made as to whether the R1 signal is turned on or not (ST123). If the R1 signal is not turned on (NO in ST123), the cold storage electromagnetic valve (**111**) remains closed in ST122 and the process is ended. If the R1 signal is turned on (YES in ST123), the cold storage electromagnetic valve (**111**) is opened (ST124) and the process is ended.

[0070] As shown in FIG. **7**, in the control process for opening/closing the freezer electromagnetic valve executed by the control section (**120**) of the freezer unit (**12**), judgment is made in the same manner as described above. That is, if it is judged from the inside temperature detected by the temperature sensor (**124**) that a request for a shift to the freezer thermo-on state is not raised (NO in ST131) or the R2 signal is turned off (NO in ST133), the freezer electromagnetic valve (**121**) remains closed (ST132) and the process is ended. If the request for a shift to the freezer thermo-on state is raised and the R2 signal is turned on (YES in ST131 and ST133), the freezer electromagnetic valve (**121**) is opened (ST134) and the process is ended.

[0071] As shown in FIG. **8**, in the control process for actuating/suspending the booster compressor executed by the control section (**120**) of the freezer unit (**12**), if a request for a shift to the freezer thermo-on state is not raised (NO in ST141) or the R2 signal is turned off (NO in ST143), the booster compressor (**131**) is suspended (ST142) and the process is ended. If the request for a shift to the freezer thermo-on state is raised and the R2 signal is turned on (YES in ST141 and ST143), the booster compressor (**131**) is actuated (ST144) and the process is ended.

[0072] In general, the freezer electromagnetic valve (**121**) is opened by the control process for opening/closing the freezer electromagnetic valve. Then, when the refrigerant is allowed to circulate in the refrigeration circuit, the refrigerant suction pressure of the

variable capacity compressor (**141**) increases and the variable capacity compressor (**141**) is actuated according to the judgment made in ST113 for the control of the thermo-on state. However, if the outside air temperature is low, the refrigerant suction pressure hardly increases and the variable capacity compressor (**141**) cannot be actuated.

[0073] In such a state, the refrigeration system (**1**) actuates the booster compressor (**131**) by the control process for actuating/suspending the booster compressor. Accordingly, the variable capacity compressor (**141**) increases in refrigerant suction pressure. As a result, the variable capacity compressor (**141**) is surely actuated according to the judgment made in ST113 for the control of the thermo-on state. Thus, according to the control processes, the variable capacity compressor (**141**) is smoothly actuated even if the outside air temperature is low.

[0074] Now, refrigeration systems (**2**) and (**3**) which are second and third embodiments of the present invention will be explained. The refrigeration systems (**2, 3**) are substantially the same as the refrigeration system of the first embodiment except that the freezer unit and the booster unit are omitted. In the explanation of the refrigeration systems (**2, 3**), the same components as those of the refrigeration system (**1**) of the first embodiment are indicated by the same reference numerals to omit specific explanation.

[0075] FIG. **9** is a view illustrating how the refrigeration system (**2**) enters the cold storage thermo-on state under a low outside air temperature.

[0076] In the refrigeration system (**2**), when a guard timer of a compressor (**241**) expires, an R1 signal from a control section (**240**) of an outdoor unit (**24**) to a control section (**210**) of a cold storage unit (**21**) is turned on (Action I). If the control section (**210**) of the cold storage unit (**21**) recognizes that a request for a shift to the cold storage thermo-on state is raised according to the value of the inside temperature detected by a temperature sensor (**214**) (Action II), an electromagnetic valve (**211**) is opened (Action III).

[0077] When the outside air temperature detected by a temperature sensor (**245**) is low,

a threshold value of the refrigerant suction pressure which is a criterion for judging whether to actuate the compressor **(241)** or not is reduced (Action IV). Then, if the refrigerant suction pressure detected by a pressure sensor **(246)** reaches the reduced threshold value (Action V), the compressor **(241)** is actuated (Action VI).

[0078] The control as described above is explained in detail with reference to FIGS. **10** and **11**.

[0079] FIG. **10** is a block diagram schematically illustrating the major structure of a control program for entering an outdoor unit thermo-on state executed by the control section **(240)** of the outdoor unit **(24)**. Specifically, the control section **(240)** executes a control program for entering the thermo-on state as shown in FIG. **11** and the control section **(210)** of the cold storage unit **(21)** executes the same control program for opening/closing the electromagnetic valve as that shown in FIG. **6**.

[0080] The control section **(240)** of the outdoor unit **(24)** includes an electromagnetic valve open/close permission section **(2401)**, a compressor actuating condition changing section **(2402)**, a compressor actuating condition judging section **(2403)** and a compressor actuating section **(2404)**.

[0081] When the guard timer of the compressor **(241)** expires, the electromagnetic valve open/close permission section **(2401)** turns on an R1 signal for permitting the electromagnetic valve **(211)** to open. The compressor actuating condition changing section **(2402)** reduces the threshold value of the refrigerant suction pressure for actuating the compressor **(241)** based on the outside air temperature Ta detected by the temperature sensor **(245)**. The compressor actuating condition judging section **(2403)** judges as to whether or not the refrigerant suction pressure LP detected by the pressure sensor **(246)** is within the predetermined range. The compressor actuating section **(2404)** actuates the compressor **(241)** when the refrigerant suction pressure LP is within the predetermined range.

[0082] The control section **(210)** of the cold storage unit **(21)** includes a cooling request

judging section (**2101**) for judging as to whether or not a request for a shift to the cold storage thermo-on state is raised and whether or not the R1 signal is turned on and an electromagnetic valve opening/closing section (**2102**) for opening the electromagnetic valve (**211**) when the request for a shift to the cold storage thermo-on state is raised and the R1 signal is turned on.

[0083] In this case, the compressor actuating condition judging section (**2403**) and the compressor actuating section (**2404**) function as an operation control means for switching the compressor (**241**) between actuated state and suspended state. Further, the compressor actuating condition changing section (**2402**) functions as a reference value changing means for reducing the threshold value of the refrigerant suction pressure which is a criterion for judging whether to actuate the compressor (**241**) or not when the outside air temperature is lower than the predetermined temperature.

[0084] According to the programs executed by the control sections (**210, 240**), even if the refrigerant suction pressure of the compressor (**241**) is reduced because of the low outside air temperature, the compressor (**241**) is actuated without fail by reducing the threshold value of the refrigerant suction pressure. More specifically, the following processes are executed. The process of controlling the opening/closing of the cold storage electromagnetic valve by the control section (**210**) of the cold storage unit (**21**) is not explained below because it is the same as that shown in FIG. **6**.

[0085] As shown in FIG. **11**, in the control process for entering the thermo-on state executed by the control section (**240**) of the outdoor unit (**24**), judgment is made as to whether or not the guard timer of the compressor (**241**) has expired (ST201). If the guard timer has not expired (NO in ST201), the process is ended. If the guard timer has expired (YES in ST201), the R1 signal is turned on to permit the cold storage electromagnetic valve (**211**) to open (ST202).

[0086] Subsequently, judgment is made as to whether or not the refrigerant suction pressure LP of the compressor (**241**) is higher than 0.4 MPa (ST203). If the refrigerant

suction pressure LP is higher than 0.4 MPa (YES in ST203), the compressor (**241**) is actuated and the process is ended.

[0087] If the refrigerant suction pressure LP is not higher than 0.4 MPa (NO in ST204), judgment is made as to whether or not the outside air temperature Ta is lower than 0°C and whether or not the refrigerant suction pressure LP is higher than 0.25 MPa (ST205). If these conditions are met (YES in ST205), the compressor (**241**) is actuated in ST204 and the process is ended.

[0088] If the conditions presented in ST205 are not met, i.e., if the outside air temperature Ta is 0°C or higher or the refrigerant suction pressure LP is not higher than 0.25 MPa (NO in ST205), judgment is made as to whether or not the outside air temperature Ta is lower than -5°C and whether or not the refrigerant suction pressure LP is higher than 0.2 MPa (ST206). If these conditions are met (YES in ST206), the compressor (**241**) is actuated in ST204 and the process is ended. If the outside air temperature Ta is not lower than -5°C or the refrigerant suction pressure LP is not higher than 0.2 MPa (NO in ST206), the process is ended without actuating the compressor (**24**).

[0089] In these processes, when the R1 signal is turned on in ST202 and the request for a shift to the cold storage unit (**21**) to the thermo-on state is raised, the cold storage electromagnetic valve (**211**) is opened. However, if the outside air temperature is low, the refrigerant suction pressure of the compressor (**241**) remains low even if the electromagnetic valve (**211**) is opened. Then, the threshold value of the refrigerant suction pressure at which the compressor (**241**) is actuated is reduced in stages from 0.4 MPa to 0.25 MPa and then to 0.2 MPa in response to the reduction in outside air temperature from a certain reference temperature to 0°C and then to -5°C, thereby allowing the actuation of the compressor (**241**). According to these control processes, the compressor (**241**) is smoothly actuated even if the outside air temperature is low.

[0090] FIG. **12** is a view illustrating how the refrigeration system (**3**) enters the cold storage thermo-on state under a low outside air temperature.

[0091] In the refrigeration system (3), when a guard timer of a compressor (**341**) expires, an R1 signal from a control section (**340**) of an outdoor unit (**34**) to a control section (**310**) of a cold storage unit (**31**) is turned on (Action I). If the control section (**310**) of the cold storage unit (**31**) recognizes from the inside temperature detected by a temperature sensor (**314**) that a request for a shift to the cold storage thermo-on state is raised (Action II), an electromagnetic valve (**311**) is opened (Action III).

[0092] When the outside air temperature is low, the saturation pressure of the refrigerant is reduced. Therefore, the refrigerant suction pressure of the compressor (**341**) remains low even if the cold storage electromagnetic valve (**311**) is opened. In such a case, when the outside air temperature is detected low (Action IV), the refrigeration system (3) begins open phase power supply to a motor of the compressor (**341**) (Action V). The open phase power supply is to apply electric current to the motor while one of three phase currents is blocked such that the coil of the motor generates heat without rotating the motor.

[0093] According to the open phase power supply, the refrigerant in the suspended compressor (**341**) raises its temperature, thereby increasing the saturation pressure of the refrigerant near the suction port of the compressor (**341**). Accordingly, the refrigerant suction pressure detected by a pressure sensor (**346**) increases. Thus, if the predetermined pressure condition is met (Action VI), the compressor (**341**) is actuated (Action VII).

[0094] The control by the refrigeration system (3) is explained with reference to FIGS. **13** and **14**.

[0095] FIG. **13** a block diagram schematically illustrating the major structure of a control program for entering the thermo-on state executed by the control section (**340**) of the outdoor unit (**34**). The control section (**340**) of the outdoor unit (**34**) executes a control program for entering the thermo-on state as shown in FIG. **14** and the control unit (**310**) of the cold storage unit (**31**) executes the same control program for opening/closing the cold storage electromagnetic valve as that shown in FIG. **6**.

[0096] The control section (**340**) of the outdoor unit (**34**) includes an electromagnetic valve open/close permission section (**3401**), an open phase power supply instructing section (**3402**), a compressor actuating condition judging section (**3403**) and a compressor actuating section (**3404**).

[0097] When the guard timer of the compressor (**341**) expires, the electromagnetic valve open/close permission section (**3401**) turns on an R1 signal for permitting the cold storage electromagnetic valve (**311**) to open. The open phase power supply instructing section (**3402**) instructs open phase power supply based on the outside air temperature Ta detected by the temperature sensor (**345**). The compressor actuating condition judging section (**3403**) judges as to whether or not the refrigerant suction pressure LP detected by the pressure sensor (**346**) is within the predetermined range. The compressor actuating section (**3404**) actuates the compressor (**341**) when the refrigerant suction pressure LP is within the predetermined range.

[0098] Similarly to the refrigeration system (**1**) of the first embodiment, the control section (**310**) of the cold storage unit (**31**) includes a cooling request judging section (**3101**) for judging as to whether or not a request for a shift to the cold storage thermo-on state is raised and whether or not the R1 signal is turned on and an electromagnetic valve opening/closing section (**3102**) for opening the electromagnetic valve (**311**) when the request for a shift to the cold storage thermo-on state is raised and the R1 signal is turned on.

[0099] In this case, the compressor actuating condition judging section (**3403**) and the compressor actuating section (**3404**) function as an operation control means for switching the compressor (**341**) between actuated state and suspended state. Further, the open phase power supply instructing section (**3404**) functions as a power supply control means for supplying open phase current to a motor of the compressor (**341**) when the compressor (**341**) is suspended, the outside air temperature is lower than a predetermined temperature and the request for a shift to the cold storage thermo-on state is raised such that the

refrigerant suction pressure increases.

[0100] Thus, when the refrigerant suction pressure of the compressor (**341**) remains low because of the low outside air temperature even if the cold storage electromagnetic valve (**311**) is opened, the programs executed by the control sections (**310, 340**) make it possible to forcibly increase the refrigerant suction pressure of the compressor (**341**) by applying open phase current to the motor of the compressor (**341**). More specifically, the following processes are executed. The control process for opening/closing the cold storage electromagnetic valve executed by the control section (**310**) of the cold storage unit (**31**) is not explained below because it is the same as that shown in FIG. **6**.

[0101] As shown in FIG. **14**, in the control process for entering the thermo-on state executed by the control section (**340**) of the outdoor unit (**34**), judgment is made as to whether or not the guard timer of the compressor (**341**) has expired (ST301). If the guard timer has not expired (NO in ST301), the process is ended. If the guard timer has expired (YES in ST301), the R1 signal is turned on to permit the cold storage electromagnetic valve (**311**) to open (ST302).

[0102] Subsequently, judgment is made as to whether or not the refrigerant suction pressure LP of the compressor (**341**) is higher than 0.25 MPa (ST303). If the refrigerant suction pressure LP is higher than 0.25 MPa (YES in ST303), the open phase power supply is prohibited and normal power supply is selected (ST304). Then, the compressor (**341**) is actuated (ST305) and the process is ended.

[0103] If the refrigerant suction pressure LP is not higher than 0.25 MPa (NO in ST303), judgment is made as to whether or not the outside air temperature Ta is lower than -5°C and whether or not the open phase power supply has continued for 5 minutes or more (ST306). If the outer temperature Ta is not lower than -5°C and the open phase power supply has continued for less than 5 minutes (NO in ST306), judgment is made as to whether the outside air temperature Ta is lower than -5°C and whether or not the suspension time of the compressor (**341**) is not shorter than 5 minutes (ST307).

[0104] In ST307, if the outside air temperature Ta is lower than -5°C and the suspension time of the compressor (**341**) is not shorter than 5 minutes (YES in ST307), the open phase power supply is permitted (ST308) and the process returns to ST301 (back to the beginning). Then, the process goes through ST301 to ST303 and judgment is made again as to whether or not the refrigerant suction pressure LP of the compressor (**341**) is higher than 0.25 MPa. If the refrigerant suction pressure LP is raised higher than 0.25 MPa (YES in ST303) by the open phase power supply, the open phase power supply is prohibited (ST304) and the compressor (**341**) is actuated (ST305) as described above. Thus, the process is ended.

[0105] Specifically, in ST307, if the outer temperature Ta is lower than -5°C and the compressor (**341**) has passed 5 minutes since it entered the thermo-off state, it is recognized that the temperature of the refrigerant in the compressor (**341**) is significantly reduced. Accordingly, the open phase power supply is carried out.

[0106] In ST303, if the refrigerant suction pressure LP is not higher than 0.25 MPa even if the open phase power supply is carried out (NO in ST303), judgment is made again in ST306 as to whether or not the outside air temperature Ta is lower than -5°C and whether or not the open phase power supply has continued for 5 minutes or more. If these conditions are met (YES in ST306), the process goes through ST304 and ST305 to actuate the compressor (**341**). Then, the process is ended. Conversely, if these conditions are not met (NO in ST306), the process returns to ST307. Specifically, in ST306, the compressor (**341**) is actuated as long as the open phase power supply has been carried out for a certain period of time to raise the refrigerant suction pressure LP to some degree, though the refrigerant suction pressure LP has not reached the predetermined value due to the low outside air temperature.

[0107] In ST307, if the outside air temperature is not lower than -5°C or the suspension time of the compressor (**341**) is less than 5 minutes (NO in ST307), the open phase power supply is not permitted and the process returns to ST301 (back to the beginning). After

that, the process goes through the steps in the same manner as described above.

[0108] In these processes, the cold storage electromagnetic valve **(311)** is opened when the R1 signal is turned on in ST302 and the request for a shift to the cold storage thermo-on state is raised. If the outside air temperature is low, the refrigerant suction pressure of the compressor **(341)** remains low. However, if the open phase current is supplied to the motor of the compressor **(341)**, the refrigerant suction pressure of the compressor **(341)** is forcibly raised, thereby actuating the compressor **(341)** without fail.

[0109] In the above-described embodiments, the refrigeration system uses the temperature sensor **(145, 245, 345)** to detect the outside air temperature directly for recognizing the temperature reduction. However, in addition to use of the temperature sensor, the temperature of the refrigerant may also be detected near the discharge port of the high pressure dome-shaped compressor **(141, 241, 341)**. In this case, if a refrigerant temperature not higher than 20°C detected near the discharge port is regarded as an indication of low outside air temperature, the reduction in outside air temperature is surely detected even if one of the two temperature sensors is broken.

[0110] In the refrigeration system **(1, 2, 3)** of the above-described embodiments, the electromagnetic valve and the expansion valve are used to control the amount of a refrigerant flow in the cold storage unit **(11, 21, 31)** and the freezer unit **(12)**. However, these valves may be replaced with other valves such as an electronic expansion valve such that the valve is opened in the thermo-on state. Just like the use of the electromagnetic valve described above, the use of the electronic expansion valve also makes the refrigerant circulate in the circuit by merely actuating the compressor.

[0111] it should be understood that the above-described embodiments are essentially preferable examples of the present invention and do not limit the present invention, application thereof and the range of application.

INDUSTRIAL APPLICABILITY

[0112] As described above, the present invention is useful for a refrigeration system including a compressor which is switchable between actuated state and suspended state.